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B-2024

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EDGERTON, GERMESHAUSEN & GRIER, INC.

FIREBALL CALCULATIONS
SHOT SANFORD
OPERATION HARDTACK PHASE II
PROJECT 15.1

REPORT NO. B-2024
29 JANUARY 1960

BOSTON, MASSACHUSETTS • LAS VEGAS, NEVADA
SANTA BARBARA, CALIFORNIA

Defense Nuclear Agency
6801 Telegraph Road
Alexandria, Virginia 22310-3398

ISST

29 May 1996

MEMORANDUM FOR DEFENSE TECHNICAL INFORMATION CENTER
ATTENTION: OCD/Mr. Bill Bush

SUBJECT: Documents for DTIC System

There is no record of your office receiving the following reports:

EGG-B-2024 (29 January 1960)
Fireball Calculations Shot Sanford
Operation Hardtack Phase II
Project 15.1

EGG-B-2013 (29 January 1960)
Fireball Calculations Shot Hamilton
Operation Hardtack Phase II
Project 15.1

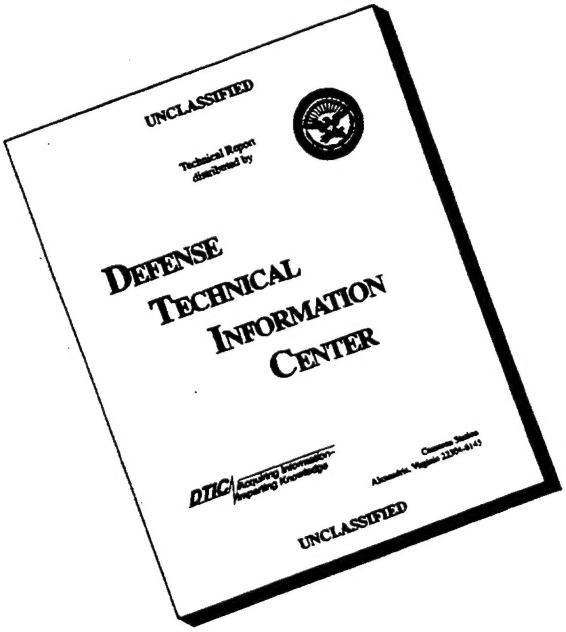
Both documents are now approved for public release.

Therefore, we are transmitting copies for inclusions into the DTIC system, if not already there.

Ardith Jarrett
ARDITH JARRETT
Chief, Technical Support

Enclosure:
A/S

DISCLAIMER NOTICE



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FIREBALL CALCULATIONS

SHOT SANFORD

OPERATION HARDTACK, PHASE II

PROJECT 15.1

Report No. B-2024
29 January 1960

Prepared by J. E. Campbell

Approved by D. F. Seacord, Jr.

EDGERTON, GERMESHAUSEN & GRIER, INC.
Boston, Mass. Santa Barbara, Calif. Las Vegas, Nev.

FIREBALL CALCULATIONS: SHOT SANFORD

1.0 INTRODUCTION

Sanford, an LRL event, was detonated on 26 October, 1958, at approximately 0220, PST, from a 1500-foot balloon in Area B-Fa of the Nevada Test Site. The fireball yield was 4.89 kt ± 0.30 kt.

2.0 CAMERA INSTRUMENTATION AND OPERATION (Table I)

Photographic coverage of fireball growth was provided by four-high-speed Eastman cameras, two each at Stations F-362 (6 x 6 No. 2) and F-369 (6 x 6 No. 3). In addition, Rapatronic cameras were located at each of these stations to record early fireball phenomena. All cameras functioned properly and provided records suitable for analysis.

The station and burst locations are shown in Fig. 1. Figure 2 contains the survey data.

3.0 RESULTS

Application of $\emptyset$ scaling to the Sanford data indicates a yield of 4.89 kt ± 0.30 kt.

An air density of 1.062 grams per liter was used in the yield calculations. This air density was based on a pressure of 864 millibars, a temperature of 9.4°C, and a relative humidity of 78 percent at the height of the device at shot time. Diameter vs time and phi vs time plots are given in Figs. 3 and 4. Table II shows average diameter vs time.

The zero-frame times of the Eastman cameras were determined by comparison with the Rapatronic diameter vs time data.

The following data sheets are included for each shot:

(a) Photo Plan and Photo Loading Chart

(b) Camera Data and Calculation Sheet

(c) Diameter Measurement Sheet

(d) E102 print-out sheet of D, t, ϕ and W (yield).

The Appendix contains photographic examples of the Sanford Fireball.

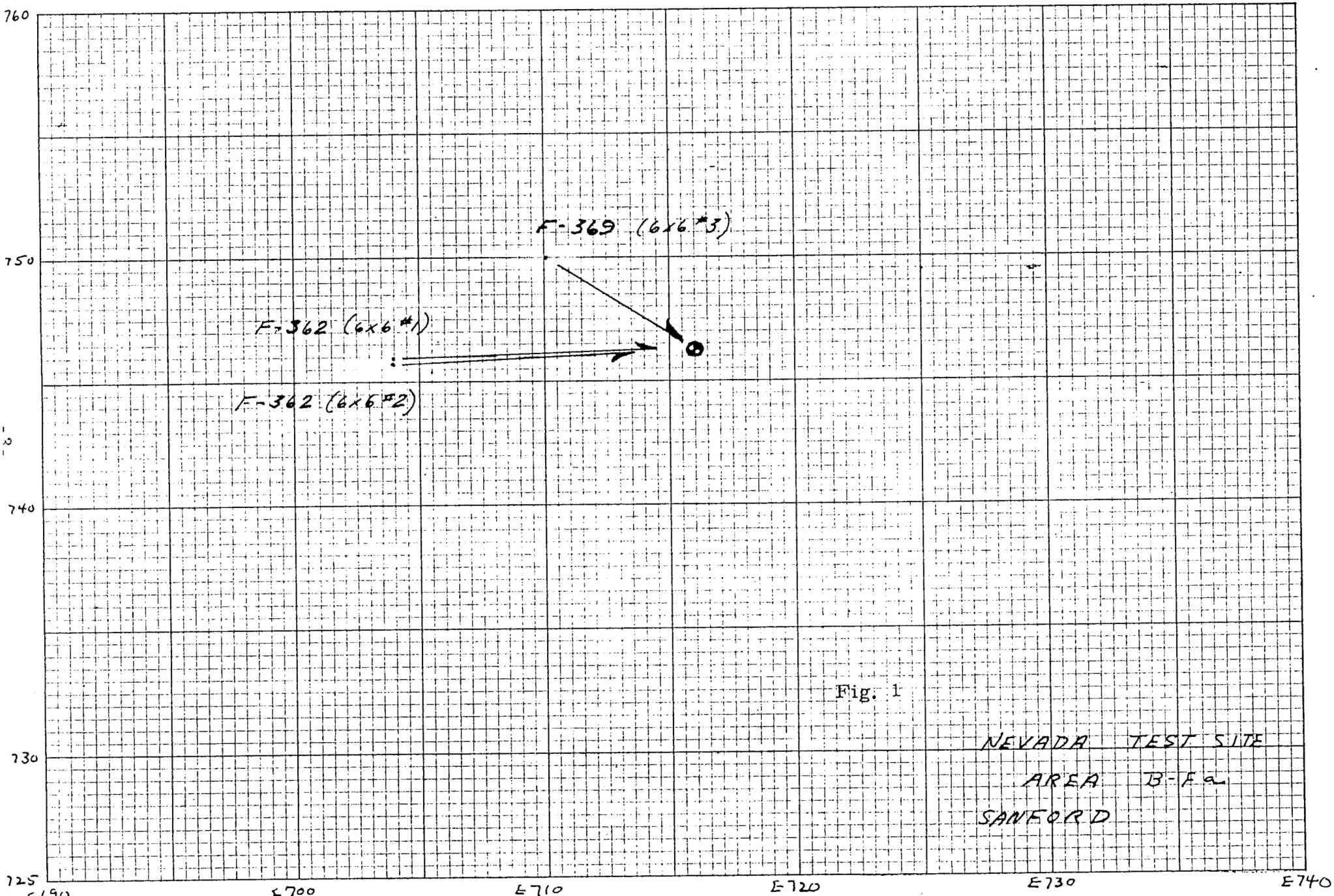


Fig. 1

NEVADA TEST SITE

AREA B-F a.

SANFORD

SANFORD

Fig. 2

DATE 10/24/58

SURVEY DATA

GZ STA. 13FA

STA.	COORDINATES			FROM Photo STA.			DIST. HOR.		TANGENTS		ANGLES	
	N	E	Z	ΔN	ΔE	ΔZ	FT.	M.	ΔE/ΔN	ΔZ/DIST.	BRG	TILT
BFA	746 250	716 000	4577*									
F362 6x6 #1	745844	703948	3091	+ 406	+ 12052	+ 1486	12058.8	3675.6	29.6847	0.12322	88°04'	7°01'
F362 6x6 #2	745825	703946	3090	+ 425	+ 12054	+ 1487	12061.5	3676.2	28.3624	0.12329	87°59'	7°02'
F369 6x6 #3	749 991	710 027	3078	- 3741	+ 5973	+ 1499	7047.8	2148.2	1.5966	0.21269	122°04'	12°00'
	BEARING ANGLES REPRESENT TRUE AZIMUTH FROM PHOTO STA. TO GROUND ZERO.											
	TILT ANGLES ARE MEASURED FROM THE PHOTO STA. TO SHOT CAB OR AIR ZERO.											
	*Includes 1500 feet height of Balloon											

FORM E17(1-55 500) NAME Analysis EDGERTON, GERMESHAUSEN & GRIER INC.

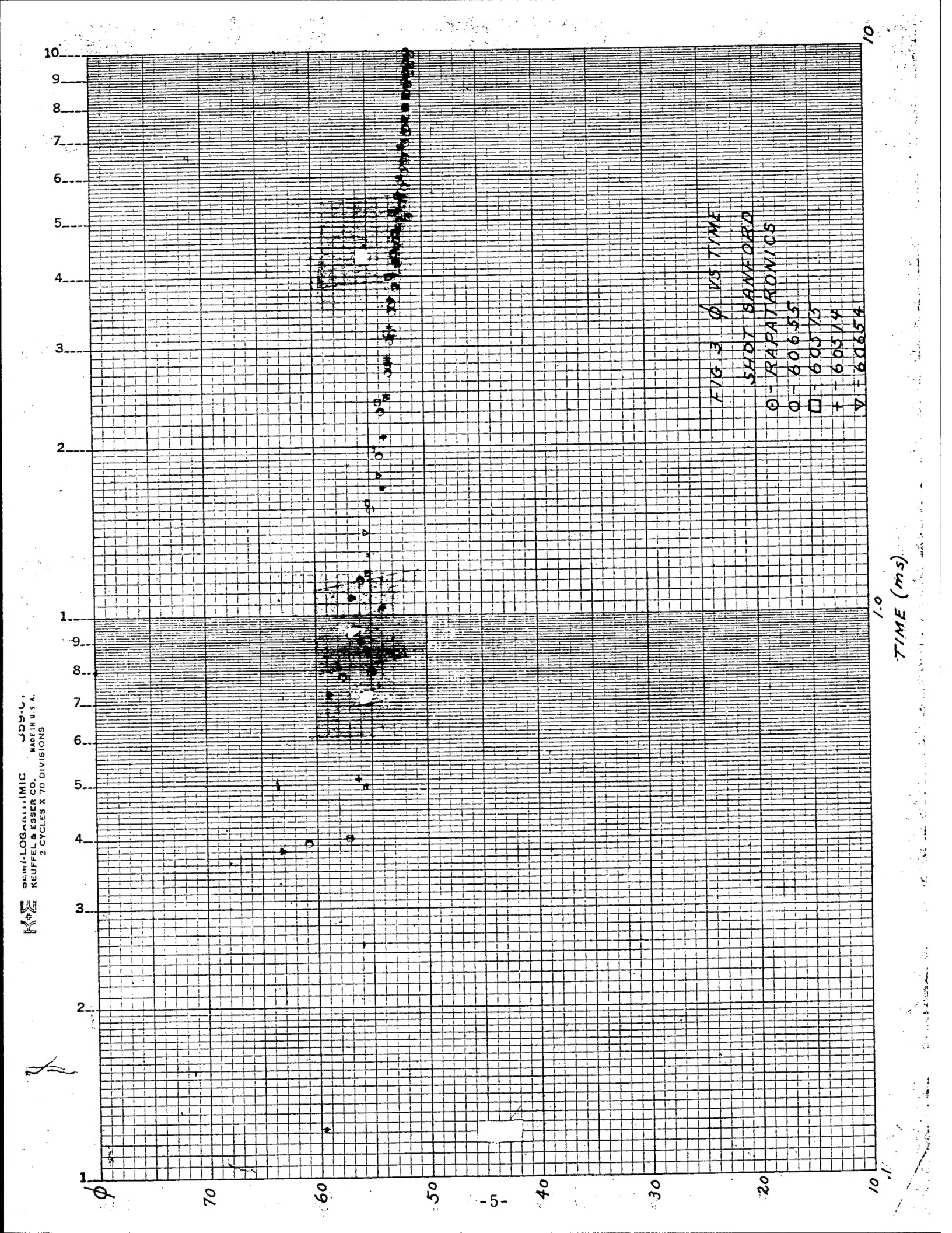


FIG 3 ϕ VS TIME
SHOT SANFORD
⊙- RAPATRONICS
○- 60655
□- 60575
+ - 60514
▽ - 60654
TIME (ms)
ϕ
10
9
8
7
6
5
4
3
2
1
70
60
50
40
30
20
10
1.0
.1
SEMI-LOGARITHMIC
KEUFFEL & ESSER CO.
2 CYCLES X 70 DIVISIONS
MADE IN U.S.A.

SANFORD

Fig. 2

SURVEY DATA

DATE 10/24/58 GZ STA. BFA

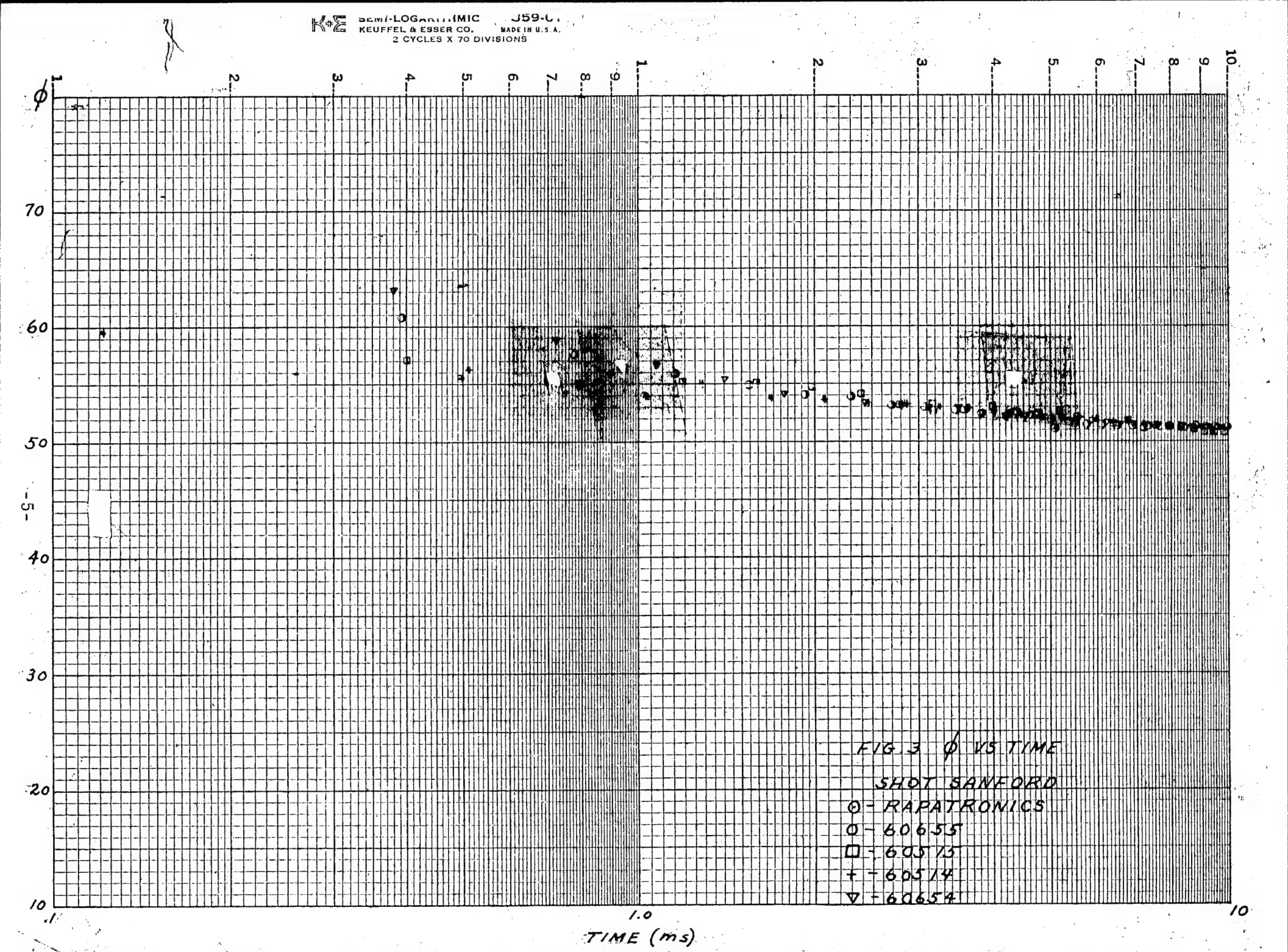
STA.	COORDINATES			FROM PHOTO STA.			DIST. HOR.		TANGENTS		ANGLES	
	N	E	Z	ΔN	ΔE	ΔZ	FT.	M.	ΔE/ΔN	ΔZ/DIST.	BRG	TILT
BFA	746 250	716 000	4577*									
F 362 6x6 #1	745844	703948	3091	+ 406	+ 12052	+ 1486	12058.8	3675.6	29.6847	0.12322	88°04'	7°01'
F362 6x6 #2	745825	703946	3090	+ 425	+ 12054	+ 1487	12061.5	3676.2	28.3624	0.12329	87°59'	7°02'
F369 6x6 #3	749 991	710 027	3078	- 3741	+ 5973	+ 1499	7047.8	2148.2	1.5966	0.21269	122°04'	12°00'

BEARING ANGLES REPRESENT TRUE AZIMUTH FROM PHOTO STA. TO GROUND ZERO

TILT ANGLES ARE MEASURED FROM THE PHOTO STA. TO SHOT CAB OR AIR ZERO.

*Includes 1500 feet height of Balloon

FORM E17(1-55 500) NAME Analysis EDGERTON, GERMESHAUSEN & GRIER INC.



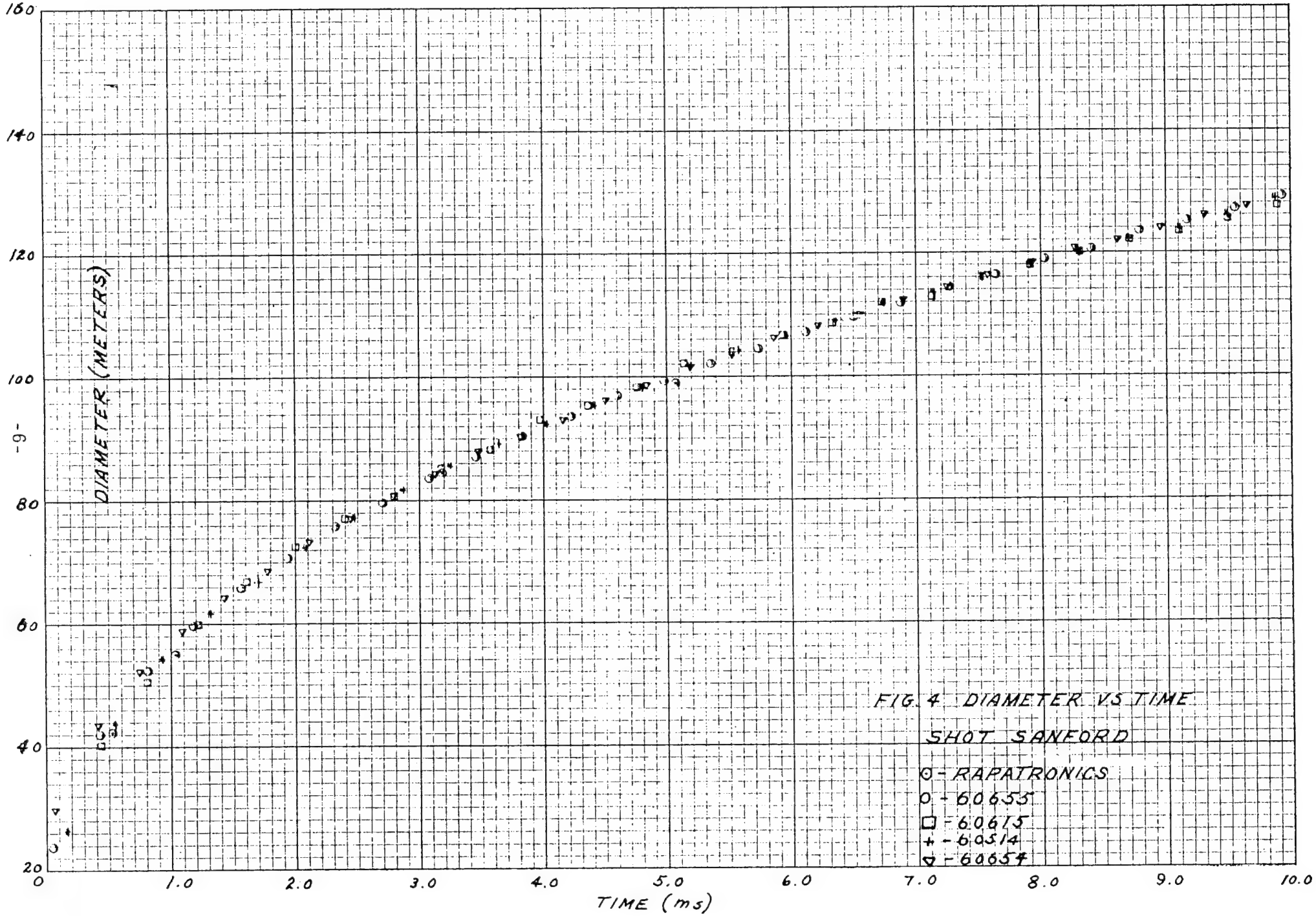


Table I

Hardtack Phase II, Sanford

Fireball Camera Distribution

Station	Camera	Qualitative Functioning
F-362 (6 x 6 No. 2)	E-34	Record
	E-7	Record
	R-30	Record
	R-34	Record
F-369 (6 x 6 No. 3)	E-25	Record
	E-6	Record
	XR-3	Record
	R-4	Record

Table II

Hardtack Phase II, Sanford

Average Diameter vs Time

Time (in msec.)	Diameter (meters) as seen from Stations 7-357 and 9-356
0.5	43.0
1.0	57.0
1.5	65.5
2.0	71.5
2.5	78.5
3.0	83.0
3.5	87.5
4.0	92.0
4.5	96.0
5.0	100.0
5.5	103.5
6.0	106.5
6.5	110.0
7.0	113.0
7.5	116.0

Table II, cont'd

Time (in msec.)	Diameter (meters) as seen from Stations 7-357 and 9-356
8.0	119.0
8.5	121.5
9.0	124.5
9.5	127.0
10.5	129.5

Table III

Hardtack Phase II, Sanford

Rapatronic Summary

Station	Film No.	Camera No.	Range (m)	F. L. (mm)	Diameter (m)	Time (msec)
F-362 (6 x 6 No. 2)	60665	R-30	3704.1	479.30	41.90	0.489
	60666	R-34	3704.1	479.03	84.03	3.182
F-369 (6 x 6 No. 3)	60658	R-4	2196.3	482.35	98.46	5.09
	60657	XR-3	2196.3	476.76	54.57	1.02

PHOTO LOADING CHART

STATION F 362 6X6 #1 EVENT SANFORD DATE 1-15-60

FILM					CAMERA			LENS		EXPOSURE			REMARKS
TYPE	EMULS. NO.	SIZE	HOLDER	PERF. NO.	NO.	RACK POS.	NOM. SPD.	FOC. MM	FILTER	APER.	SHUTTER RHEO.	W/M²	
ECT 1229		35X11	CASSETTE	60 653	FR #2	=	16 000	10"	ND-2	f/6.0	MAX	1.5X10⁻⁵	

DATE FILM LOADED _____ DATE CAMERA LOADED _____ DATE EXPOSED _____

REMARKS _____

FINAL

FORM E-40

EDGERTON, GERMESHAUSEN & GRIER, INC.

STATION TYPE 6X6 L

DISTANCE GZ 12058.8

DISTANCE OBJECT 12150.2

STATION	G Z	DIFF.
N 745 944	746 250	406
E 703 948	716 000	12052
Z 3051	4577*	1486

TILT GZ −0° 4' OBJ 7° 01'

DATE 10-24-58

POSTED

1500' BALLOON

CAMERA			LENS			FIELD TARGET H/V	AIMING			POWER			MARKER		DELAY	FILM	PURPOSE	REMARKS
NO.	NOM SPD.	RACK POS.	FOC. MM	S/N	FILTER		OBJECT	H	V	VOLTS	SHUT RHEO.	TIME ON/OFF	TYPE	S/N				
#2 FR	16000	=	10"	4498746	NO 2		F.B.	AIM IN FIELD		115AC 240C	MAX	-1/+1	200	#1	=	ECT 1229	EXP.	

REMARKS * Includes 1500 ft., height of balloon.

FINAL

FORM E-60 A

EDGERTON, GERMESHAUSEN & GRIER, INC.

FILM					CAMERA			LENS		EXPOSURE			REMARKS
TYPE	EMULS. NO.	SIZE	HOLDER	PERF. NO.	NO.	RACK POS.	NOM. SPD.	FOC. MM	FILTER	APER	SHUTTER RHEO.	W/M²	
MF	1112-9-02	16-100	H.S. Reel	60514	E-34	C-1	2500	63	ND-1 W-12	f 8.0	40/80	2×10^5	
MF	↓	16-100	H.S. Reel	60515	E-7	C-2	2500	6.3	ND-1 W-12	f 9.0	40/80	4×10^5	
TRI-X	5243 359-10	35-200	MIT MAG	60516	M-26	B 2	100	18.5	W-12	f 16.0	170°	WESTON 700	
RP	6141 676-E1	2¼-3¼	RAP HOLDER	60665	R-30	A-1	4ms COIL	480	ND-1	f 11.0	BULB	1.5×10^7	500 μs DELAY
RP	↓	2¼-3¼	RAP HOLDER	60666	R-34	A-2	40ms COIL	480	ND-1	f 11.0	BULB	1.5×10^6	3000 μs DELAY
D KDC	264607	16-50	U-MAG	60519	22 GSP	L B-4	64	9.5	=	f 5.5	133°	WESTON 700	
D KDC	↓	16-50	U-MAG	60520	5 GSP	R B-4	64	9.5	=	f 4.5	133°	WESTON 600	
ECT 1229	1229 393	35-400	Daylight Spool	60521	#1 35FF	C-3	2000	152	ND-3	f 8.0	=	5×10^5	
					ACTUAL	RAP	DELAYS						
					R-30			486.7 μs	+ 2 μs	half coil delay			
					R-34			3161.7 μs	+ 20 μs	half coil delay			

DATE FILM LOADED _____ DATE CAMERA LOADED _____ DATE EXPOSED _____

REMARKS _____

FINAL

FORM E-40

EDGERTON, GERMESHAUSEN & GRIER, INC.

STATION TYPE 6X6 "A"

DISTANCE GZ 12061.5 ft.

DISTANCE OBJECT 12153 ft.

STATION	GZ	DIFF.
N 745 825	746 250	425
E 703 946	716 000	12054
Z 3090	4577*	1487

TILT GZ −0°04' OBJ +2°02'

GZ STA. [illegible]

DATE 10-24-58

POSTED

1500' BALLOON

CAMERA NO.	CAMERA NOM SPD.	CAMERA RACK POS.	LENS FOC. MM	LENS S/N	LENS FILTER	FIELD TARGET H/V	AIMING OBJECT	AIMING H	AIMING V	POWER VOLTS	POWER SHUT RHEO.	POWER TIME ON/OFF	MARKER TYPE	MARKER S/N	DELAY μs	FILM	PURPOSE	REMARKS
E34	2500	C-1	63	ET 1254	ND-1 W-12	1.750 1.350	F.B	0°00'	+0°02'	120DC	40/80	−1.5/+1.5	200	12	=	MF	15.1	
E-7	2500	C-2	63	RC 486	ND-1 W-12	1.750 1.350	F.B.	0°00'	+0°02'	120DC	NO/80	−1.5/+1.5	200	4	=	MF	15.1	
M-26	100	B-2	18.5	304862	W-12	16.100 12.240	CLOUD	0°00'	+4°20'	120DC	170°	−5/+30	200	12	=	TRIX	15.1	
R-30	4μs COIL	A-1	480	773953	ND-1	1.270 1.270	F.B	0°00'	+0°02'	115AC 24DC	BULB	=	FM	5	500	RP	15.1	CAM #32
R-34	40μs COIL	A-2	480	773948	ND-1	1.270 1.270	F.B.	0°00'	+0°02'	115AC 24DC	BULB	=	FM	5	3000	RP	15.1	CAM #40
22 GSP	64	L B-4	9.5	240190	=	13.200 8.930	DOC.	0°00'	+0°15'15	24DC	133°	−5/+30	=	=	=	D KDC	15.1	
5 GSP	64	R B-4	9.5	240259	=	13.200 8.930	DOS	0°00'	+0°15'15	24DC	133°	−5/+30	=	=	=	D KDC.	15.1	
#1 35FF	2000	C-3	152	90589	ND-3	1.920 1.450	F.B	0°00'	+0°02'	120DC	=	−3/12	200	4	=	ECT 1209	15.1	
							ACTUAL RAP DELAYS											
							R-30		486.7	μs	+2	μs	half coil delay					
							R-34		3161.7	μs	+20	μs	half coil delay					

REMARKS * Includes 1500', height of balloon.

FINAL

FORM E-60 A

EDGERTON, GERMESHAUSEN & GRIER, INC.

PHOTO LOADING CHART

STATION F-369 6X6 #3 EVENT Sanford DATE 1-15-60

FILM					CAMERA			LENS		EXPOSURE			REMARKS
TYPE	EMULS. NO.	SIZE	HOLDER	PERF. NO.	NO.	RACK POS.	NOM. SPD.	FOC. MM	FILTER	APER.	SHUTTER RHEO.	W/M²	
MF	1112-9-02	16-100	H.S. REEL	60654	E-25	A-2	2500	63	ND-1 W-12	f8.0	40/80	2X10⁵	
MF	↓	16-100	H.S. REEL	60655	E-6	A-3	2500	40	ND-1 W-12	f9.0	40/80	4X10⁵	
TRIX	5243 359-10	35-200	MIT MAG	60656	M-5	B-2	100	18.5	W-12	f16.0	170°	WESTON 700	
RP	6141 676 E1	2¼-3¼	RAP HOLDER	60657	XR-3	A-1	4MS COIL	480	=	f11.0	BULB	3X10⁶	1000 μs DELAY
RP	↓	2¼-3¼	RAP HOLDER	60658	R-4	B-1	40MS COIL	480	=	f11.0	BULB	3X10⁵	5000 μs DELAY
D KDC	264607	16-50	U-MAG	60659	20 GSP	L R-3	64	9.5	=	f5.0	133°	WESTON 700	
D KDC	↓	16-50	U-MAG	60660	66 GSP	R B-3	64	9.5	=	f6.0	133°	WESTON 800	
					ACTUAL RAP DELAYS								
					XR-3		10	10.7 μs + 2 μs half coil delay					
					R-4		50	53.1 μs + 20 μs half coil delay					

DATE FILM LOADED _____ DATE CAMERA LOADED _____ DATE EXPOSED _____

REMARKS _____

FINAL

FORM E-40

EDGERTON, GERMESHAUSEN & GRIER, INC.

PHOTO PLAN

STATION NO. F-369 | STATION TYPE 6X6 #3 | DISTANCE GZ 7047.8 ft. | DISTANCE OBJECT 7206 ft.

BRG 122 04 | GZ STA. BFA | DATE 10/24/58 | POSTED

STATION	GZ	DIFF.	TILT
N 749 991	746 250	3741	GZ 0°
E 710 027	716 000	5973	OBJ 12°
Z 3078	4577*	1499	

CAMERA NO.	NOM SPD.	RACK POS.	LENS FOC. MM	LENS S/N	LENS FILTER	FIELD TARGET H/V	AIMING OBJECT	AIMING H	AIMING V	POWER VOLTS	POWER SHUT RHEO.	POWER TIME ON/OFF	MARKER TYPE	MARKER S/N	DELAY μs	FILM	PURPOSE	REMARKS
F-25	2500	A-2	63	ET 1207	ND-1 W-12	1.041 .804	F.B.	0°00'	+12°	120DC	40/80	-1.5/+1.5	200	101	=	MF	15.1	
E-6	2500	A-3	40	3232586	ND-1 W-12	1.630 1.265	F.B.	0°00'	+12°	120DC	40/80	-1.5/+1.5	200	14	=	MF	15.1	
M-5	100	B-2	18.5	365767	W-12	9.650 7.330	Cloud	0°00'	+19°05'	120DC	170°	-5/+30	200	101	=	TRIX	15.1	
XR-3	4μs COIL	A-1	480	274695	=	.753 .753	F.B.	0°00'	+12°	115AC 24DC	BULB	=	FM	26	1000	RP	15.1	Can #17
R-4	40μs COIL	B-1	480	273750	=	.753 .753	F.B.	0°00'	+12°	115AC 24DC	BULB	=	FM	26	5000	RP	15.1	Can #13
60 GSP	64	L B-3	9.5	255	=	7.920 5.350	Doc.	0°00'	+15°15'	24DC	133°	-5/+30	=	=	=	D KDC	15.1	
66 GSP	64	R B-3	9.5	255319	=	7.920 5.350	Doc	0°00'	+15°15'	24DC	133°	-5/+30	=	=	=	D KDC	15.1	

ACTUAL CAP DELAYS

XR-3	1017.7 ms	± 2 ms	half coil delay
R-4	5073.1 ms	± 20 μs	half coil delay

REMARKS

* Includes 1500 ft., height of balloon

FINAL

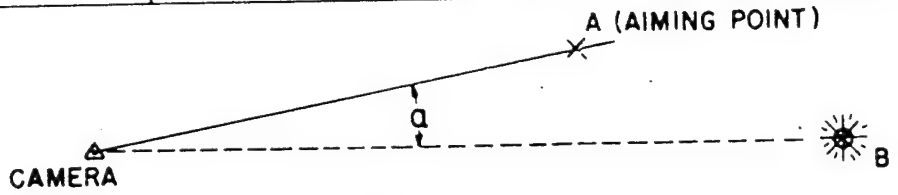
EDGERTON, GERMESHAUSEN & GRIER, INC.

FORM E-60 A

OPERATION: HARDTACK PHASE II

CAMERA DATA & CALCULATIONS

FILM NO. 60655	f STOP	CAMERA NO. E-6	CALCULATED BY: JEC
STATION NO. F-369 6x6 #3	EQ. AP.	LENS TYPE	DATE: 12/1/58
RACK POS.	N D	LENS NO. 3232586	
TEST SANFORD	COLOR FILTER:	β = EL. ANGLE	



A. $R^{0}/_{A} = CB_h \cos\alpha \cos\beta + (H_B - H_C) \sin\beta$

α = 0° 00′	β = 12°	H_B = 4577 ft
$\cos\alpha$ = 1.0000	$\cos\beta$ = 0.97815	H_C = 3078 ft
CB_h = 2148.2 m	$\sin\beta$ = 0.20791	ΔH = 1499 ft = 456.9 m
$CB_h \cos\alpha \cos\beta$ = 2101.3 m	$\Delta H \sin\beta$ = 94.99 m	$R^{0}/_{A}$ = 2196.3 m

B. FOCAL LENGTH 39.95 mm (3232586)

C. MAGNIFICATION FACTOR (meters/in.) 1396.5

D. ZERO TIME CORRECTION 0.01 ms

DIAMETER MEASUREMENTS

'NFORD

FILM NO. 60655 E-6
6×6 #3

Mag.	D_1	D_2	D_3	D_{avg} (m)	FLEXOWRITER D_{avg} (m) xxx.xx	t (ms)
48.15	0079	0082		23.35		
	0145	0143		41.76		
	0179	0180		52.06		
	0206	0203		59.31		
	0227	0225		65.54		
	0244	0241		70.33		
	0261	0259		75.40		
	0273	0273		79.17		
	0287	0287		83.23		
	0300	0298		86.71		
	0311	0310		90.05		
	0323	0321		93.38		
	0334	0332		96.52		
	0343	0332		99.04		
28.90	0210	0210		101.47		
	0215	0215		103.89		
	0221	0220		106.55		
	0226	0225		108.96		
	0231	0230		111.38		
	0237	0235		114.04		
	0241	0239		115.97		
	0246	0245		118.63		
	0251	0247		120.32		
	0255	0255		123.22		
	0258	0259		124.91		
	0263	0262		126.64		
	0266	0267		128.77		
	0270	0271		130.71		
	0272	0274		131.91		
	0275	0277		133.36		

RH GGO TYPED BY

11/5/58 DATE

FIREBALL CALCULATIONS

SHOT SANFORD FILM NO. 60655

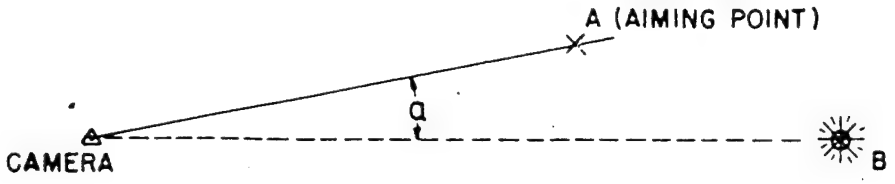
DATE 11/5/58

D	t	ln D	Int	$t^{2/5}$	ϕ	W
23.35	.01	3.150 53	4.605 09 -	.1 59064	1 46.795	920.909
41 76	39	3 732 01	94153 -	6 861 80	608 58	11278
52 06	77	3 952 38	26135 -	9 007 35	57797	8713
59 31	1 15	4 082 71	13968	10 57464	560 86	7498
65 54	1 54	4 182 59	43185	11 885 60	551 42	6887
70 33	1 92	4 253 15	65233	12 981 44	541 77	6305
75 40	2 30	4 322 80	83284	13 953 38	540 37	6224
79 17	2 69	4 371 63	98947	14 855 56	532 93	5807
83 23	3 07	4 421 67	1 12166	15 662 19	531 40	5725
86 71	3 45	4 462 65	1 23841	16 410 99	528 36	5563
90 05	3 83	4 500 44	1 34293	17 111 66	526 24	5452
93 38	4 22	4 536 73	1 43990	17 788 43	524 94	5385
96 57	4 60	4 570 27	1 52610	18 412 44	524 48	5361
99 04	4 98	4 595 47	1 60543	19 006 11	521 09	5190
101 47	5 36	4 619 80	1 67893	19 573 14	518 41	5058
103 89	5 75	4 643 32	1 74913	20 130 59	516 08	4945
106 55	6 13	4 668 56	1 81311	20 652 41	515 92	4938
108 96	6 51	4 690 91	1 87326	21 155 30	515 04	4896
111 38	6 89	4 712 87	1 93001	21 641 01	514 67	4878
114 04	7 28	4 736 47	1 98510	22 123 17	515 47	4917
115 97	7 66	4 753 25	2 03601	22 578 36	513 63	4829
118 63	8 04	4 775 94	2 08447	23 020 21	515 32	4909
120 32	8 42	4 790 09	2 13067	23 449 65	513 09	4804
123 22	8 81	4 813 92	2 17596	23 878 31	516 03	4943
124 91	9 19	4 827 55	2 21817	24 284 94	514 35	4863
126 84	9 57	4 842 88	2 25865	24 681 28	513 91	4842
128 77	9 95	4 858 01	2 29750	25 067 89	513 68	4832
130 71	10 33	4 872 97	2 33505	25 447 24	513 65	4830
131 91	10 72	4 882 12	2 37206	25 826 73	510 74	4695
133 36	11 10	4 893 06	2 40687	26 188 87	509 22	4625

OPERATION: HARDTACK PHASE II

CAMERA DATA & CALCULATIONS

FILM NO. 60514	f STOP	CAMERA NO. E-34	CALCULATED BY
STATION NO. F-362 6x6 #2	EQ. AP.	LENS TYPE	DATE: 12/1/58
RACK POS.	N D	LENS NO. ET-1254	
TEST SANFORD	COLOR FILTER:	β = EL. ANGLE	



A. $R^0/_A = CB_h \cos \alpha \cos \beta + (H_B - H_C) \sin \beta$

α = 0° 00′	β = 7° 02′	H_B = 4577 ft
cos α = 1.0000	cos β = 0.99248	H_C = 3090 ft
CB_h = 3676.2 m	sin β = 0.12245	ΔH = 1487 ft = 453.
$CB_h \cos \alpha \cos \beta$ = 3648.6m	$\Delta H \sin \beta$ = 55.49 m	$R^0/_A$ = 3704.1 m

B. FOCAL LENGTH 63.91 mm (ET-1254)

C. MAGNIFICATION FACTOR (meters/in.) 1472.1

D. ZERO TIME CORRECTION 0.12 ms

DIAMETER MEASUREMENTS

SHOT SANFORD FILM NO. E-34 F-362

60514

Fr. No.	Mag.	D_1	D_2	D_3	D_{avg} (m)	FLEXOWRITER D_{avg} (m) xxx.xx	t (ms)
0	48.15	0083	0084		25.53		
12		0142	0140		43.10		
2		0174	0177		53.65		
3		0200	0200		61.14		
4		0216	0218		66.34		
5		0235	0235		71.84		
6		0249	0252		76.58		
7		0264	0266		81.01		
8		0278	0278		84.98		
9		0289	0291		88.65		
10		0300	0301		91.86		
11		0310	0310		94.77		
12		0320	0320		97.82		
13		0330	0331		101.03		
14		0338	0340		103.63		
15		0347	0346		105.93		
16	28.90	0214	0211		108.25		
17		0219	0218		111.30		
18		0222	0222		113.09		
19		0226	0227		115.38		
20		0232	0230		117.67		
21		0234	0235		119.45		
22		0240	0238		121.75		
23		0243	0243		123.78		
24		0247	0247		125.82		
25		0253	0251		128.37		
26		0257	0256		130.66		

READ BY GGO JEC TYPED BY

DATE 11-5-58 DATE

REMARKS:

FIREBALL CALCULATIONS

SHOT SANFORD FILM NO. 60514

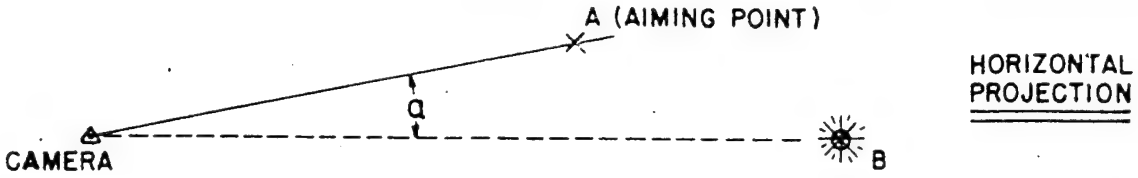
DATE 11/5/58

D	t	ln D	ln t	$t^{2/5}$	ϕ	W
25.53	.12	3.23978	-2.12033	.428214	50619	10176
43 10	51	3763 59	-677 35	763892	56422	7725
5365	90	398245	-105 29	958758	55957	7412
61.14	129	411309	-.25462	1107218	55219	6936
6634	168	419472	-.51886	1230654	53906	6149
7184	207	427440	-.72752	1337776	53701	6033
7658	246	433834	-.90008	1433377	53426	5880
8101	285	439462	-1.04727	1520300	53285	5803
8498	325	442249	-1.17866	1602343	53034	5668
8865	364	448477	-1.29204	1676684	52872	5582
9196	403	452033	-1.39384	1746366	52600	5440
9477	442	455149	-1.48620	1812089	52298	5285
9782	481	458311	-1.57072	1874402	52187	5229
10103	520	461546	-1.64864	1933743	52245	5259
10363	559	464082	-1.72092	1990471	52063	5167
10593	598	466274	-1.78834	2044880	51802	5039
10825	637	468438	-1.85152	2097211	51616	4949
11170	676	471215	-1.91095	2147668	51823	5050
11309	715	472810	-1.96707	2196420	51488	4888
11538	754	474815	-2.02021	2243611	51426	4859
11767	793	476781	-2.07068	2289363	51398	4846
11945	832	478283	-2.11872	2333779	51183	4745
12175	872	480191	-2.16569	2378043	51197	4752
12378	911	481846	-2.20944	2420020	51148	4729
12582	950	483491	-2.25132	2460902	51127	4719
12837	989	485489	-2.29147	2500748	51332	4815
13066	1028	487259	-2.33021	2539800	51444	4868

OPERATION: HARDTACK PHASE II

CAMERA DATA & CALCULATIONS

FILM NO. 60515	f STOP	CAMERA NO. E-7	CALCULATED BY: DB
STATION NO. F-362 6×6 #2	EQ. AP.	LENS TYPE	DATE: 10/26/58
RACK POS.	N D	LENS NO. RC 486	
TEST SANFORD	COLOR FILTER:	β = EL. ANGLE	



A. $R^{o}/_{A} = CB_h \cos\alpha \cos\beta + (H_B - H_C) \sin\beta$

α = 0° 00′	β = + 7° 02′	H_B = 4577 ft
cos α = 1.0000	cos β = 0.9925	H_C = 3090 ft
CB_h = 3676.2 m	sin β = 0.1224	ΔH = 1487 ft = 453.2 m
$CB_h \cos\alpha \cos\beta$ = 3648.6 m	$\Delta H \sin\beta$ = 55.47 m	$R^{o}/_{A}$ = 3704.1 m

B. FOCAL LENGTH 63.93 mm (RC 486)

C. MAGNIFICATION FACTOR (meters/in.) 50.73

D. ZERO TIME CORRECTION 0.40 ms

DIAMETER MEASUREMENTS

SHOT Sanford

E-7 F 362
FILM NO. 60515

Fr. No.	Mag.	D_1	D_2	D_3	D_{avg} (m)	FLEXOWRITER D_{avg} (m) xxx.xx	t (ms)
0	29.00	0078			39.58		
1		0099	0098		50.23		
2		0117	0117		59.32		
3		0131	0130		66.42		
4		0142	0141		72.05		
5		0150	0151		76.62		
6		0157	0158		80.17		
7		0167	0167		84.74		
8		0173	0173		87.78		
9		0182	0181		92.35		
10		0186	0188		94.88		
11		0194	0191		97.93		
12		0200	0199		101.48		
13		0205	0203		103.51		
14		0209	0208		106.05		
15		0213	0213		108.08		
16		0220	0219		111.63		
17		0222	0221		112.64		
18		0228	0227		115.69		
19		0232	0232		117.72		
20		0236	0236		119.75		
21		0240	0240		121.78		
22		0242	0243		123.30		
23		0246	0247		125.33		
24		0249	0252		127.36		
25		0252	0252		127.86		
26		0260	0256		130.91		
27		0266	0258		132.94		

READ BY GGO JEC TYPED BY

DATE 10/26/58 DATE

REMARKS:

EDGERTON, GERMESHAUSEN & GRIER, INC.

FIREBALL CALCULATIONS

SHOT SANFORD FILM NO. 60515

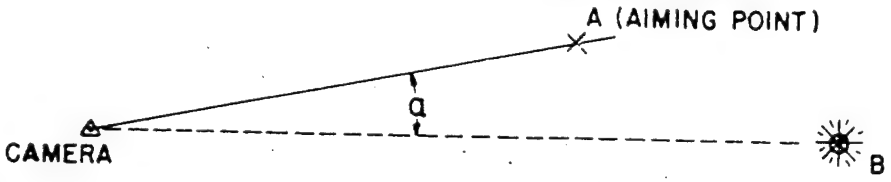
DATE 10/26/58

D	t	ln D	Int	$t^{2/5}$	ϕ	W
39.58	.40	3.678240	.914[illegible]	.[illegible]93164	57100	8200
5023	.79	3.914[illegible]	[illegible]	[illegible]10028	55196	6921
5977	1.19	4.089372	17388	1.072030	55390	7038
6547	1.59	4.196668	46381	1.203849	55214	6933
7205	1.98	4.277233	68309	1.314212	54823	6691
7662	2.38	4.338896	86702	1.414548	54165	6299
8017	2.78	4.384419	1.02239	1.505247	53260	5789
8474	3.17	4.439666	1.15373	1.586440	53415	5974
8778	3.57	4.474091	1.27262	1.663707	52761	5593
9235	3.97	4.525665	1.37884	1.735919	53199	5786
9488	4.36	4.552564	1.47253	1.802213	52646	5473
9703	4.76	4.584223	1.56028	1.866587	52464	5370
10148	5.15	4.619900	1.63898	1.926288	52681	5499
10351	5.55	4.639666	1.71375	1.984764	52152	5214
10505	5.95	4.656397	1.78332	2.040771	51965	5119
10708	6.34	4.682891	1.84680	2.093255	51632	4997
11153	6.74	4.715511	1.90799	2.145123	52078	5186
11264	7.14	4.724111	1.96567	2.195190	51312	4885
11589	7.53	4.750883	2.01888	2.242419	51591	4917
11732	7.93	4.768223	2.07068	2.289363	51420	4856
11875	8.32	4.785534	2.11872	2.333779	51311	4845
12104	8.72	4.800216	2.16569	2.378043	51210	4758
12280	9.11	4.814557	2.20944	2.420020	50949	4638
12433	9.51	4.830091	2.25237	2.461936	50907	4619
12736	9.91	4.846609	2.29349	2.502764	50887	4610
12[illegible]96	10.30	4.85[illegible]91	2.33215	2.541771	50303	4351
13[illegible]91	10.70	4.87[illegible]50	2.37019	2.58[illegible]44	50[illegible]5	4547
13[illegible]94	11.09	4.88[illegible]30	2.40537	2.61[illegible]943	50780	4541

OPERATION: *HARDTACK PHASE II*

CAMERA DATA & CALCULATIONS

FILM NO. *60654*	f STOP	CAMERA NO. *E-25*	CALCULATED BY: *JEC*
STATION NO. *F-369 6x6 #3*	EQ. AP.	LENS TYPE	DATE: *12/1/58*
RACK POS.	N D	LENS NO. *ET-1207*	
TEST *SANFORD*	COLOR FILTER:	β = EL. ANGLE	



A. $R^{o}/_{A} = CB_h \cos \alpha \cos \beta + (H_B - H_C) \sin \beta$

α = *0° 00'*	β = *12°*	H_B = *4577 ft*
$\cos \alpha$ = *1.0000*	$\cos \beta$ = *0.97815*	H_C = *3078 ft*
CB_h = *2148.2 m*	$\sin \beta$ = *0.20791*	ΔH = *1499 ft = 456.9 m*
$CB_h \cos \alpha \cos \beta$ = *2101.3 m*	$\Delta H \sin \beta$ = *94.99 m*	$R^{o}/_{A}$ = *2196.3 m*

B. FOCAL LENGTH *64.10 m m. (ET-1207)*

C. MAGNIFICATION FACTOR (meters/in.) *870.28*

D. ZERO TIME CORRECTION *0.03 ms*

DIAMETER MEASUREMENTS

SHOT Sanford E-25 STA-369

FILM NO. 60654

Fr. No.	Mag.	D_1	D_2	D_3	D_{avg} (m)	FLEXOWRITER D_{avg} (m) xxx.xx	t (ms)
0	48.15,	0160	0161		29.00		
1		0236	0240		43.01		
2		0287	0286		51.72		
3		0322	0324		58.37		
4		0353	0353		63.79		
5	28.90	0226	0226		68.05		
6		0243	0242		73.02		
7		0254	0255		76.63		
8		0267	0266		80.24		
9		0278	0279		83.86		
10		0291	0290		87.47		
11		0299	0298		89.88		
12		0308	0307		92.59		
13		0318	0318		95.75		
14		0326	0327		98.31		
15		0335	0335		100.87		
16		0342	0342		102.98		
17	19.23	0234	0233		105.68		
18		0238	0238		107.72		
19		0242	0242		109.53		
20		0247	0248		112.02		
21		0252	0252		114.06		
22		0256	0257		116.09		
23		0261	0261		118.13		
24		0266	0266		120.39		
25		0269	0269		121.75		
26		0274	0273		123.79		
27		0279	0277		125.82		
28		0282	0281		127.44		

READ BY ggo rh TYPED BY

DATE 11-5-58 DATE

REMARKS:

FIREBALL CALCULATIONS

SHOT SANFORD FILM NO. 60654

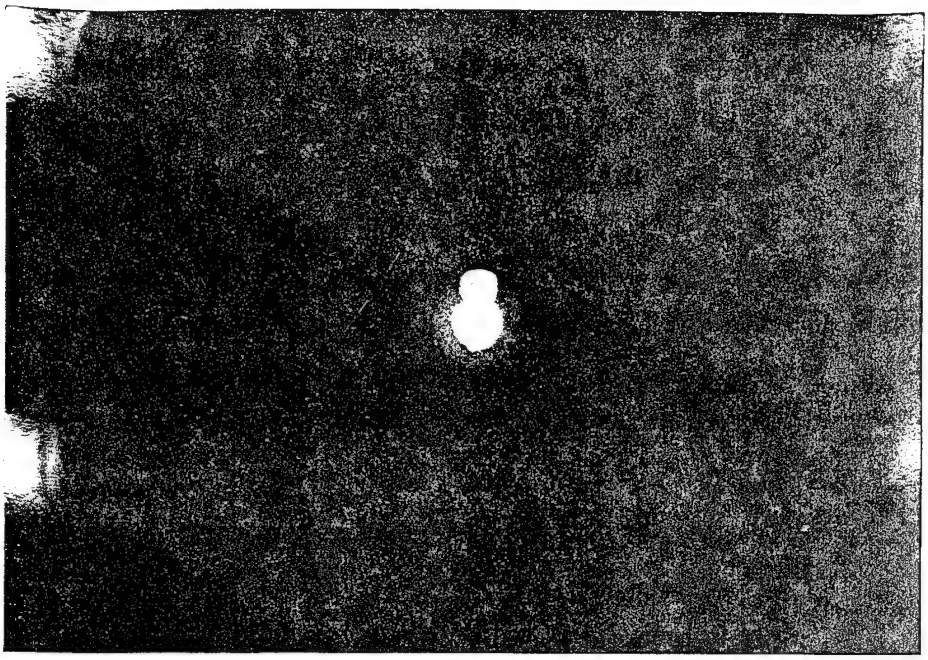
DATE 11/5/58

D	t	ln D	ln t	$t^{2/5}$	ϕ	W
2970	.03	3.367625	-3.506558	.245999	11786	30758
4301	38	3.761550	-.967551	.679086	63335	13768
5177	72	3.946460	-.328554	.976851	59040	9692
5837	107	4.066774	-.067600	1.027412	56812	7996
6379	141	4.155562	.344363	1.147348	55597	7176
6805	176	4.220018	.565370	1.253761	54276	6363
7302	210	4.290071	.741900	1.345494	54269	6359
7663	244	4.339000	.891920	1.428704	53635	6307
8024	279	4.385806	1.025980	1.507411	53230	5773
8386	313	4.429221	1.141020	1.578309	53129	5719
8747	348	4.471737	1.247070	1.646795	53115	5711
9089	382	4.498855	1.340320	1.709377	52580	5429
9259	416	4.528824	1.425590	1.768684	52349	5311
9575	451	4.561176	1.506350	1.826754	52415	5345
9831	485	4.588809	1.579000	1.880618	52275	5274
10097	520	4.613888	1.648640	1.933743	52163	5217
10298	554	4.634454	1.711940	1.983334	51922	5098
10568	588	4.660038	1.771480	2.031136	52029	5151
10772	623	4.679047	1.829290	2.078651	51822	5049
10953	657	4.696613	1.882440	2.123309	51584	4934
11202	691	4.719860	1.932910	2.166612	51702	4991
11406	726	4.736664	1.982340	2.209883	51613	4948
11609	760	4.754429	2.028140	2.250741	51578	4931
11813	795	4.771771	2.073200	2.291672	51547	4916
12039	829	4.790067	2.115100	2.330408	51660	4971
12175	863	4.801101	2.155310	2.368193	51410	4851
12379	898	4.818454	2.195070	2.406153	51447	4869
12592	932	4.834491	2.233220	2.443156	51519	4903
12741	966	4.846778	2.266290	2.477371	51429	4860

APPENDIX

SHOT SANFORD

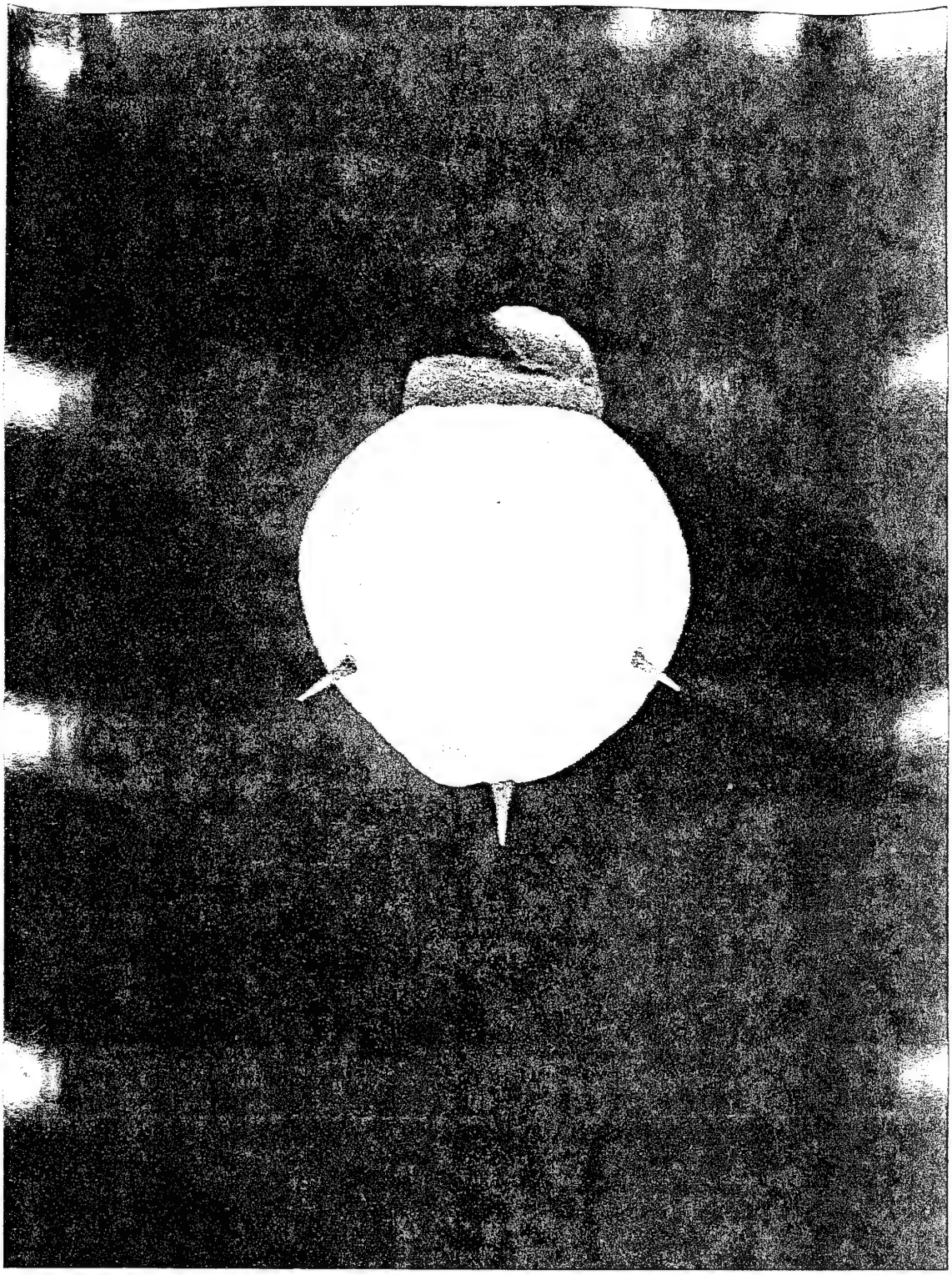
PHOTOGRAPHIC EXAMPLES



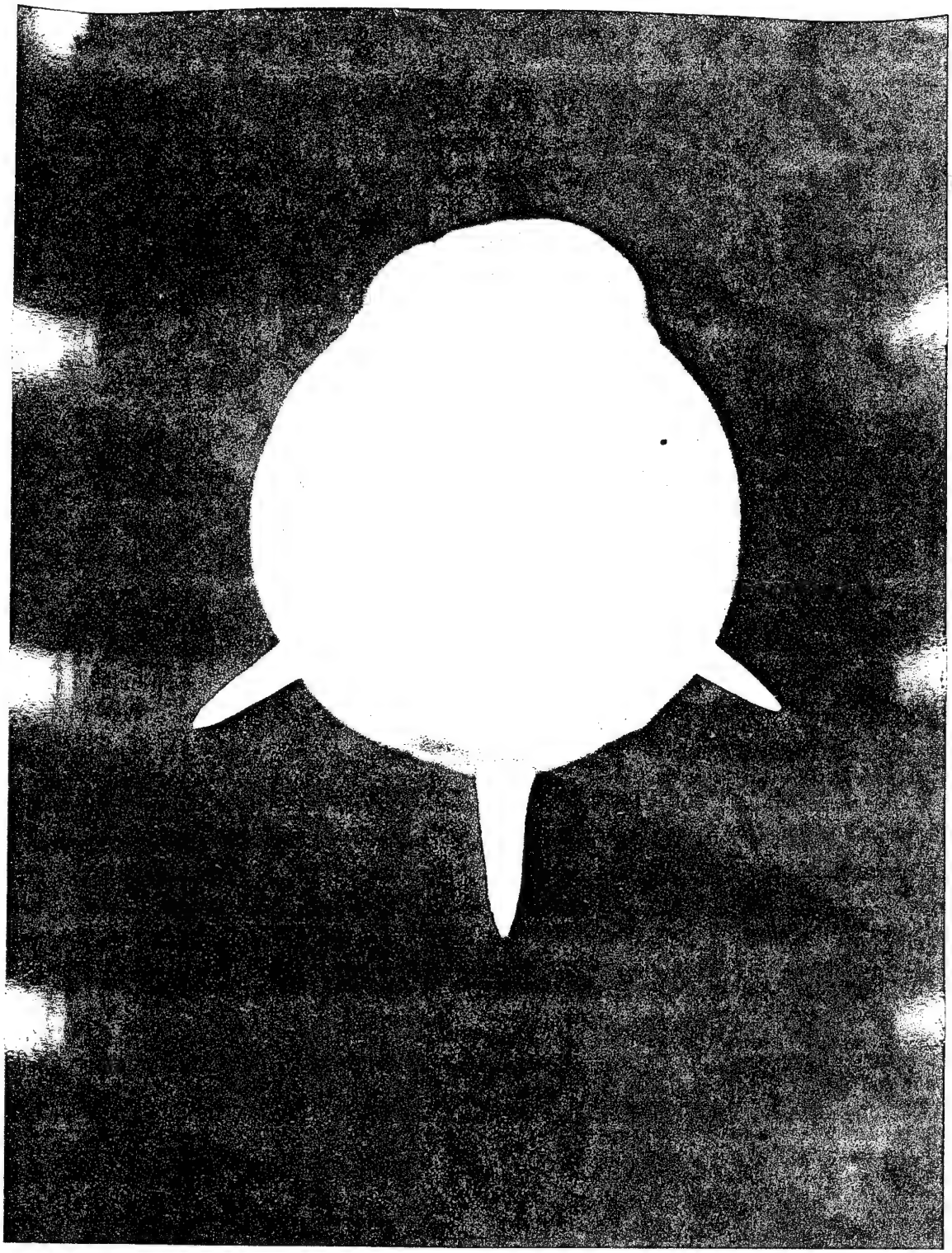
Camera: E-34

Station: F-362 (6 x 6 No. 2)

Time: .12 msec



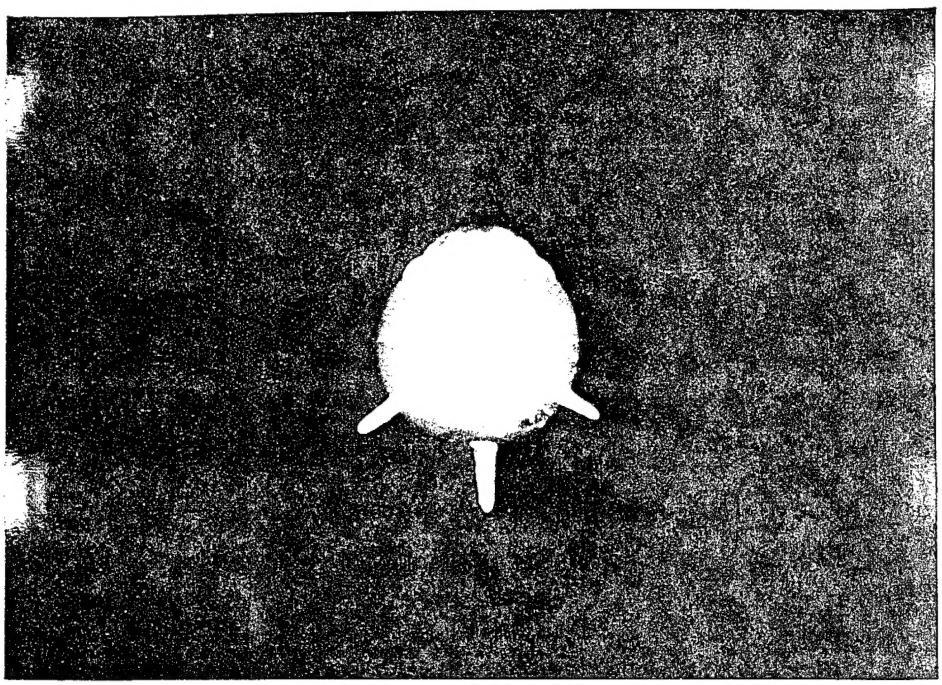
Camera: R-30
Station: F-362 (6 x 6 No. 2)
Time: 0.49 msec



Camera: R-34

Station: F-362 (6 x 6 No. 2)

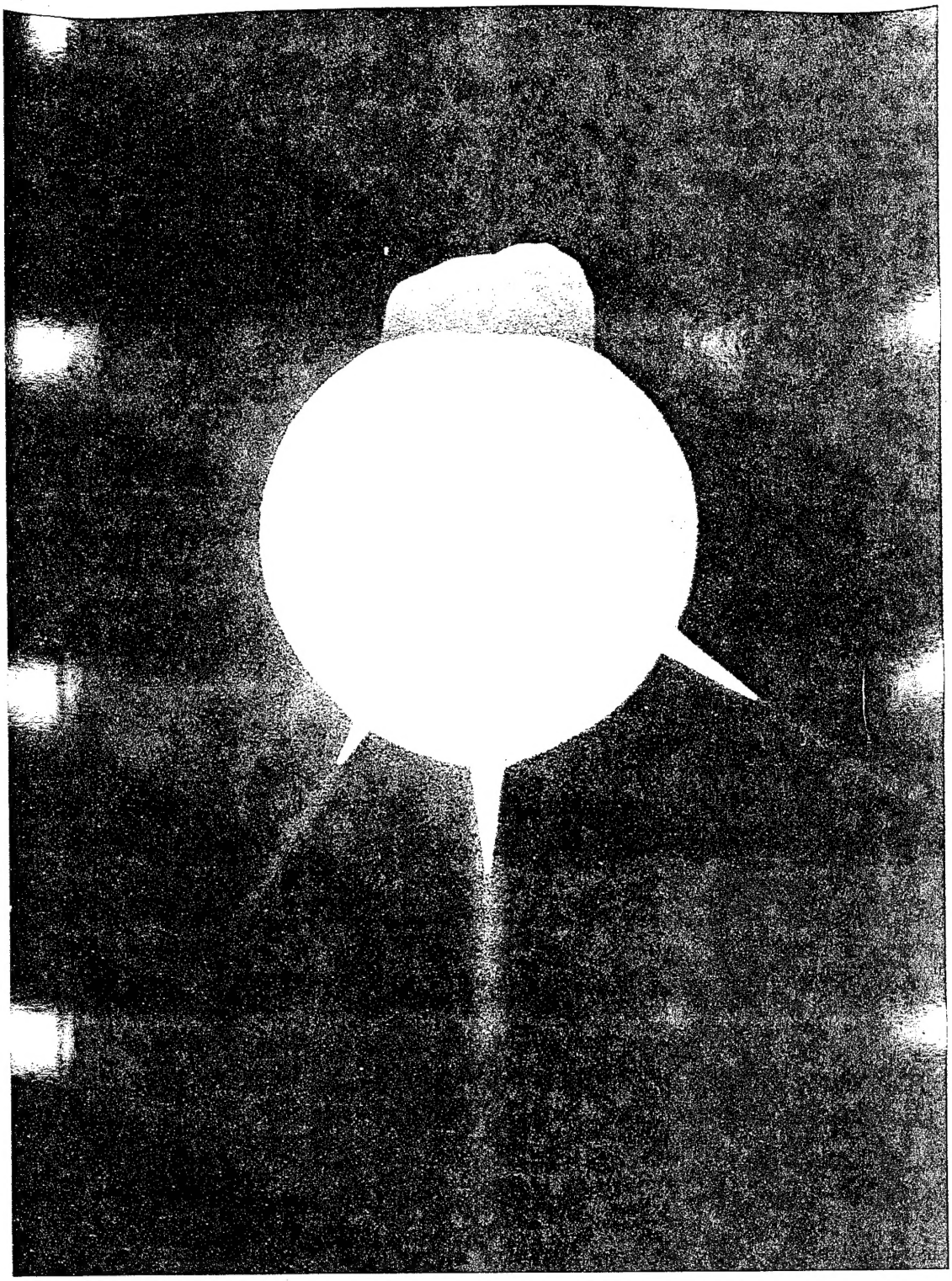
Time: 3.18 msec



Camera: E-34

Station: F-362 (6 x 6 No. 2)

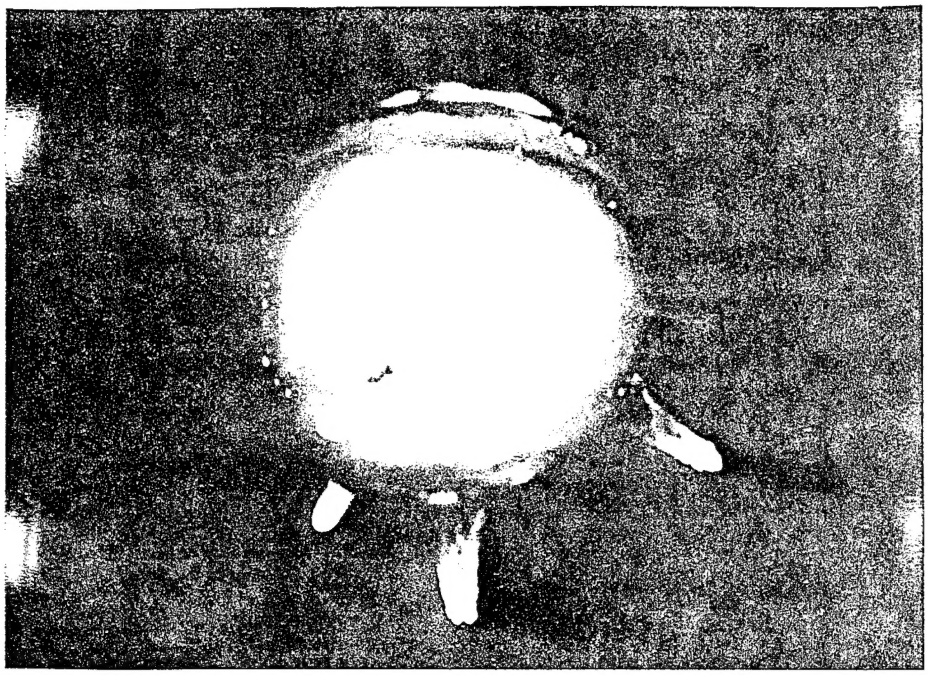
Time: 6.37 msec



Camera: XR-3

Station: F-369 (6 x 6 No. 3)

Time: 1.02 msec



Camera: E-25

Station: F-369 (6 x 6 No. 3)

Time: 10.01 msec

Distribution

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1	Dr. W. E. Ogle, LASL Test Group Director
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1	Dr. J. F. Mullaney, Group J-10,
1	EG&G, Boston
1	EG&G, Las Vegas